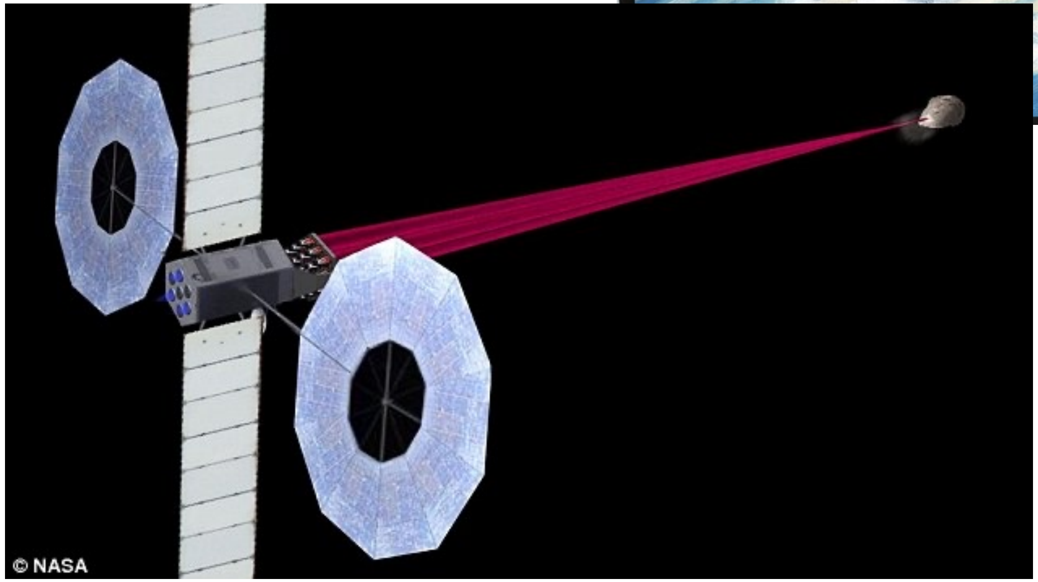
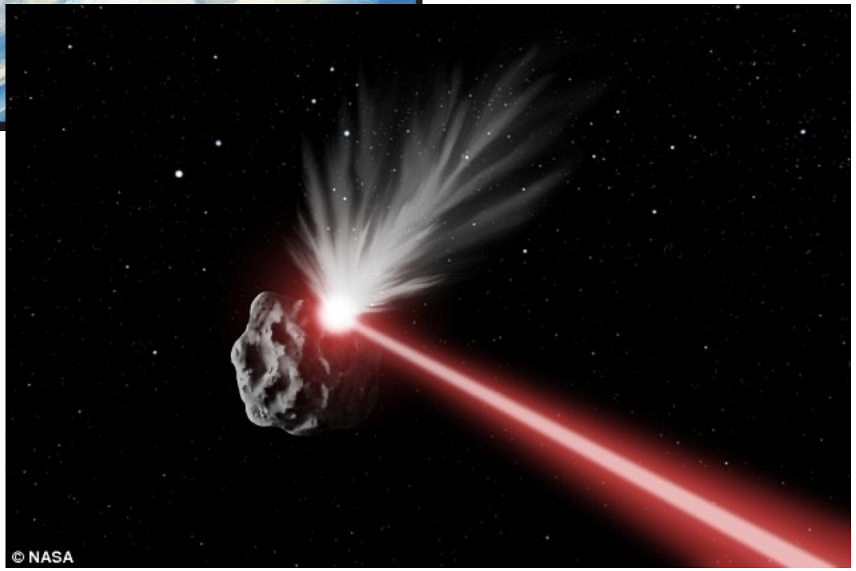
Il contributo dell'analisi chimica con tecniche laser per l'esplorazione dello spazio e della terra

Prof. Alessandro De Giacomo


© NASA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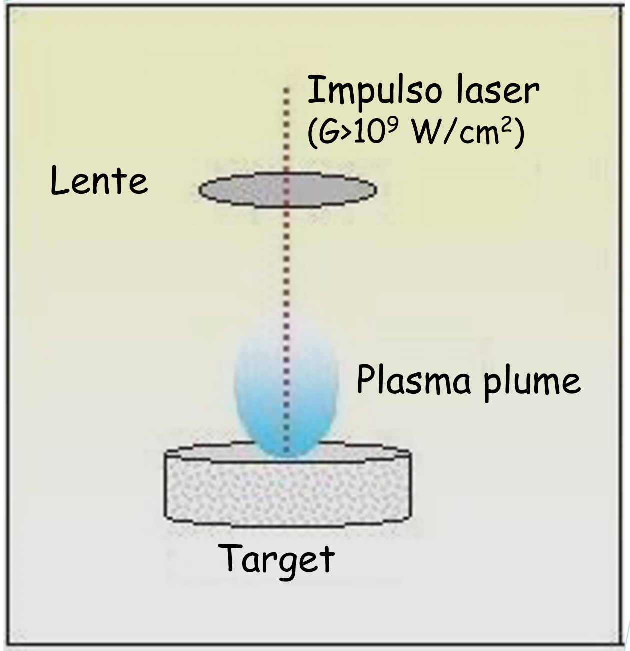
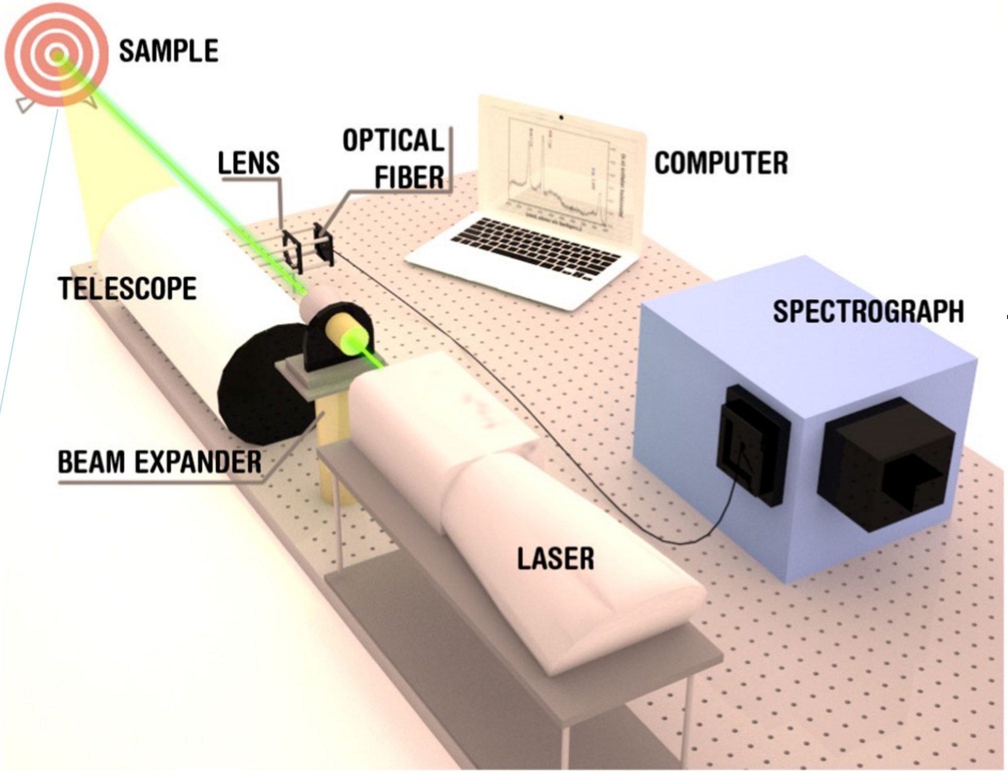
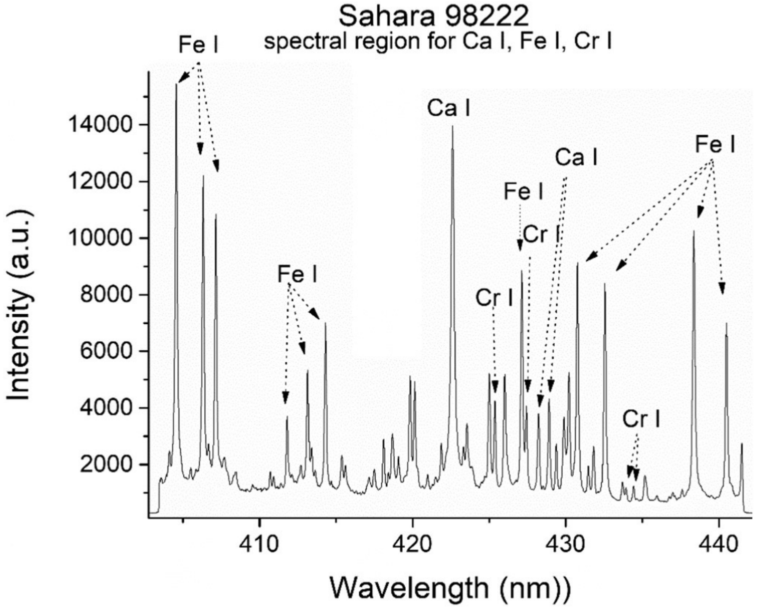
LIBS
Laser Induced Breakdown Spectroscopy

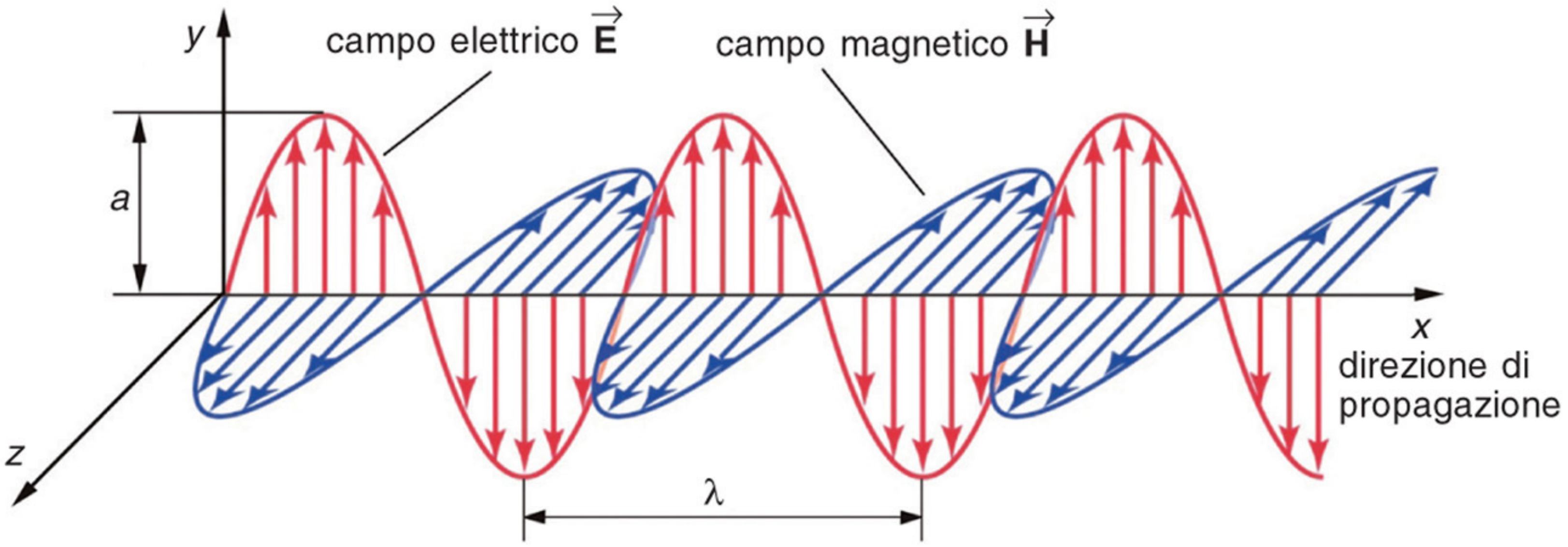


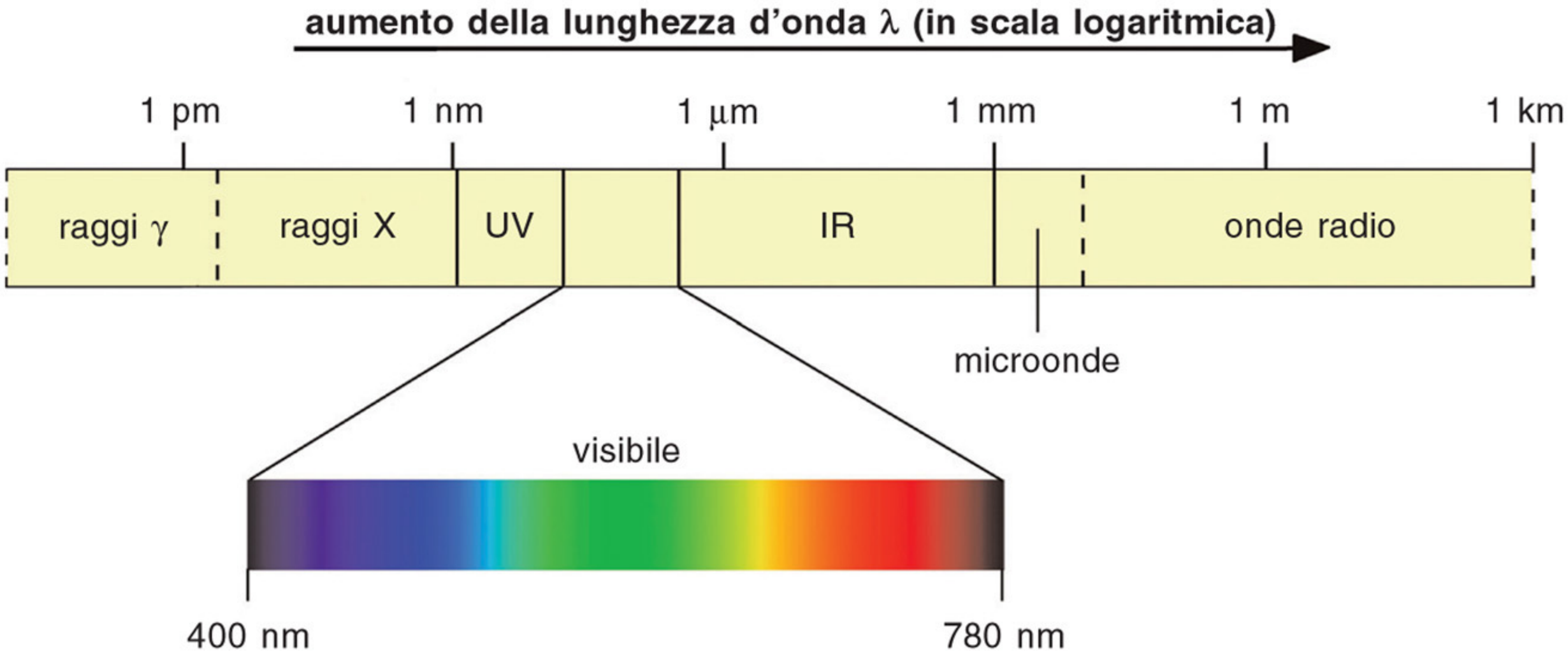


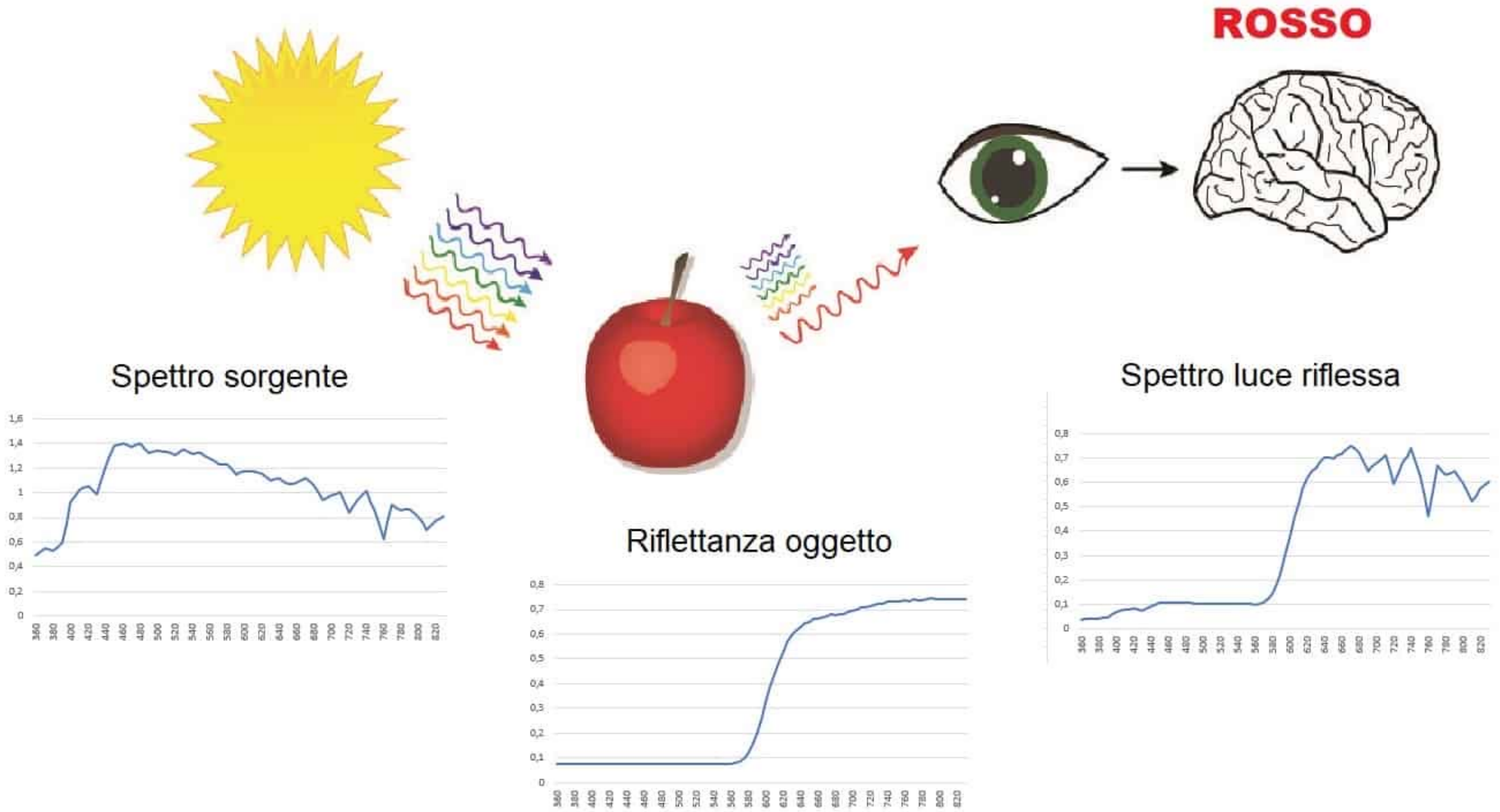


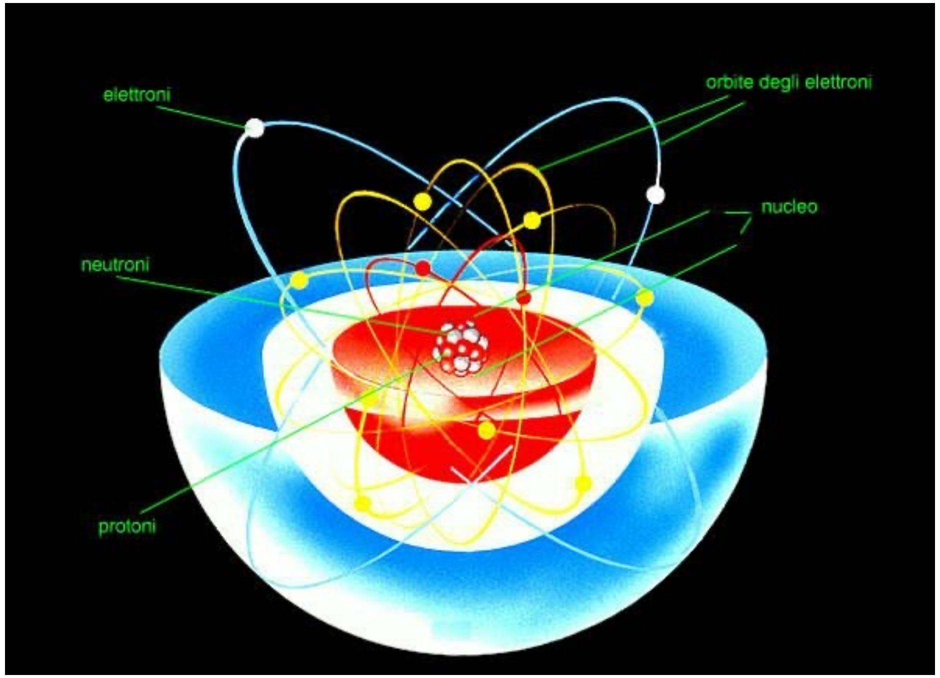
T = 10000 K
N = 10^{26} m^{-3}

Dell'Aglio M., López-Claros M., Laserna J.J., Longo S., De Giacomo A., Stand-off laser induced breakdown spectroscopy on meteorites: calibration-free approach (2018) Spectrochimica Acta - Part B Atomic Spectroscopy, 147, pp. 87 - 92


y
campo elettrico $\vec{E}$
campo magnetico $\vec{H}$
a
x
direzione di propagazione
z
λ


aumento della lunghezza d'onda λ (in scala logaritmica)
1 pm
1 nm
1 µm
1 mm
1 m
1 km
raggi γ
raggi X
UV
IR
onde radio
microonde
visibile
400 nm
780 nm

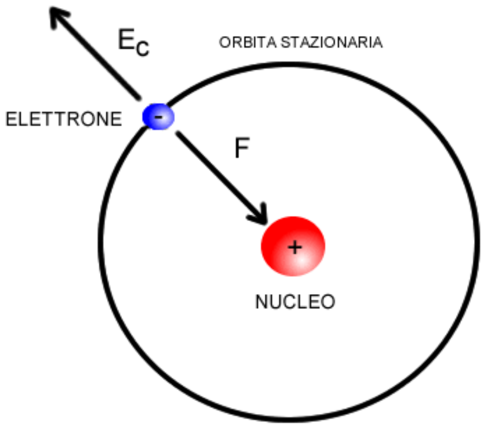

ROSSO
Spettro sorgente
Riflettanza oggetto
Spettro luce riflessa

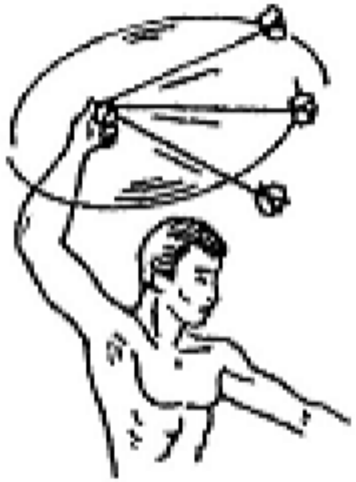


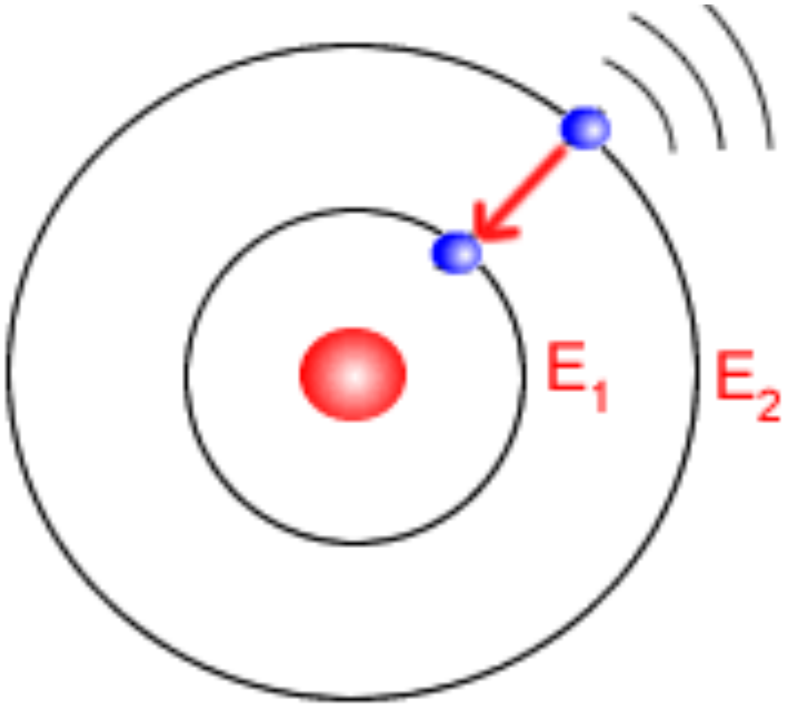
Massa del protone = 1,67262171 X 10^{-27} kg

Massa del neutrone = 1,67492729 X 10^{-27} kg

Massa dell’elettrone = 9.1093826 X 10^{-31} kg

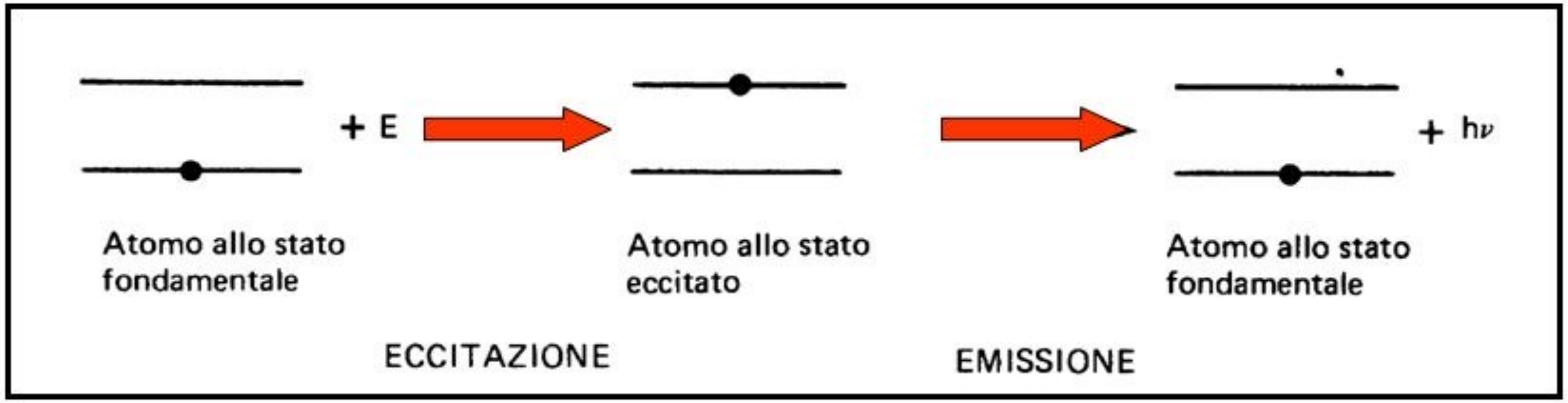


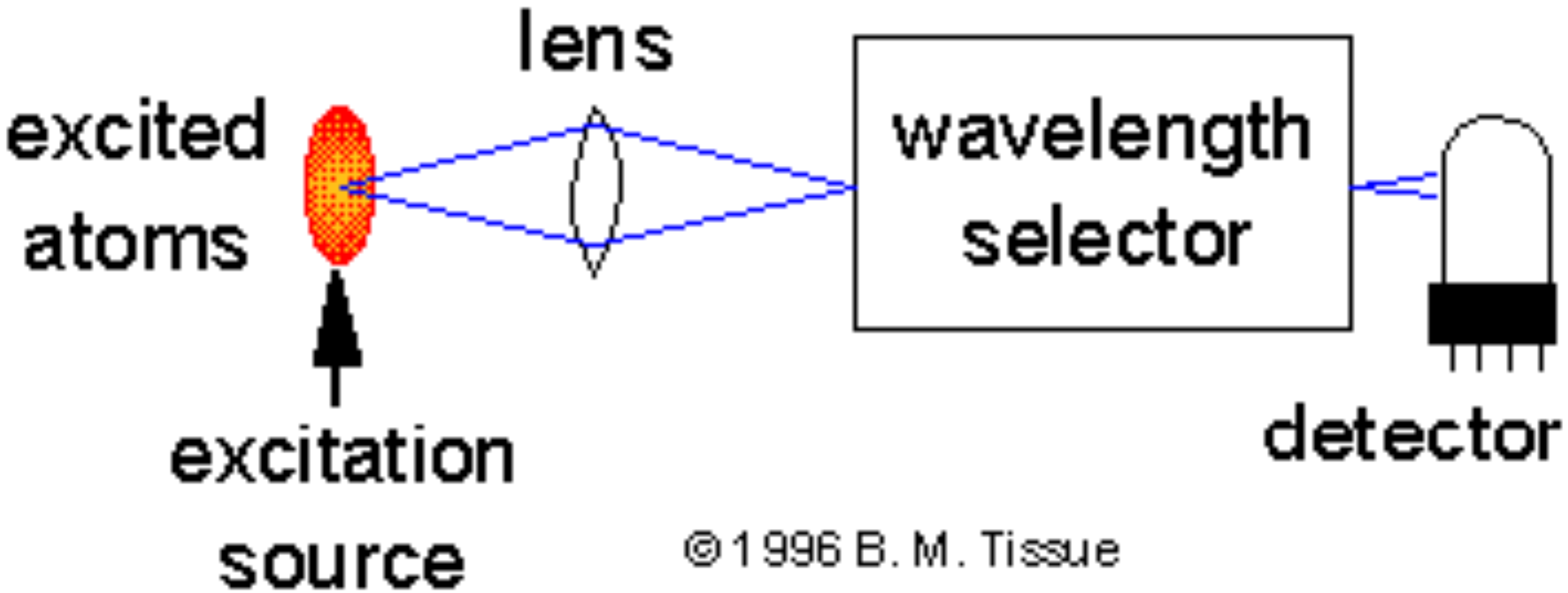


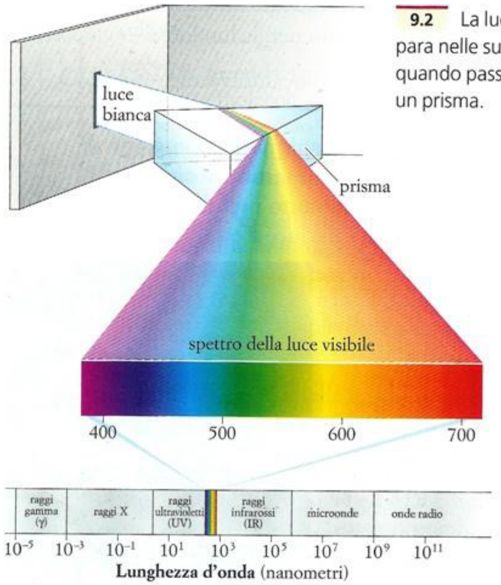


$$E_2 - E_1 = h\nu$$

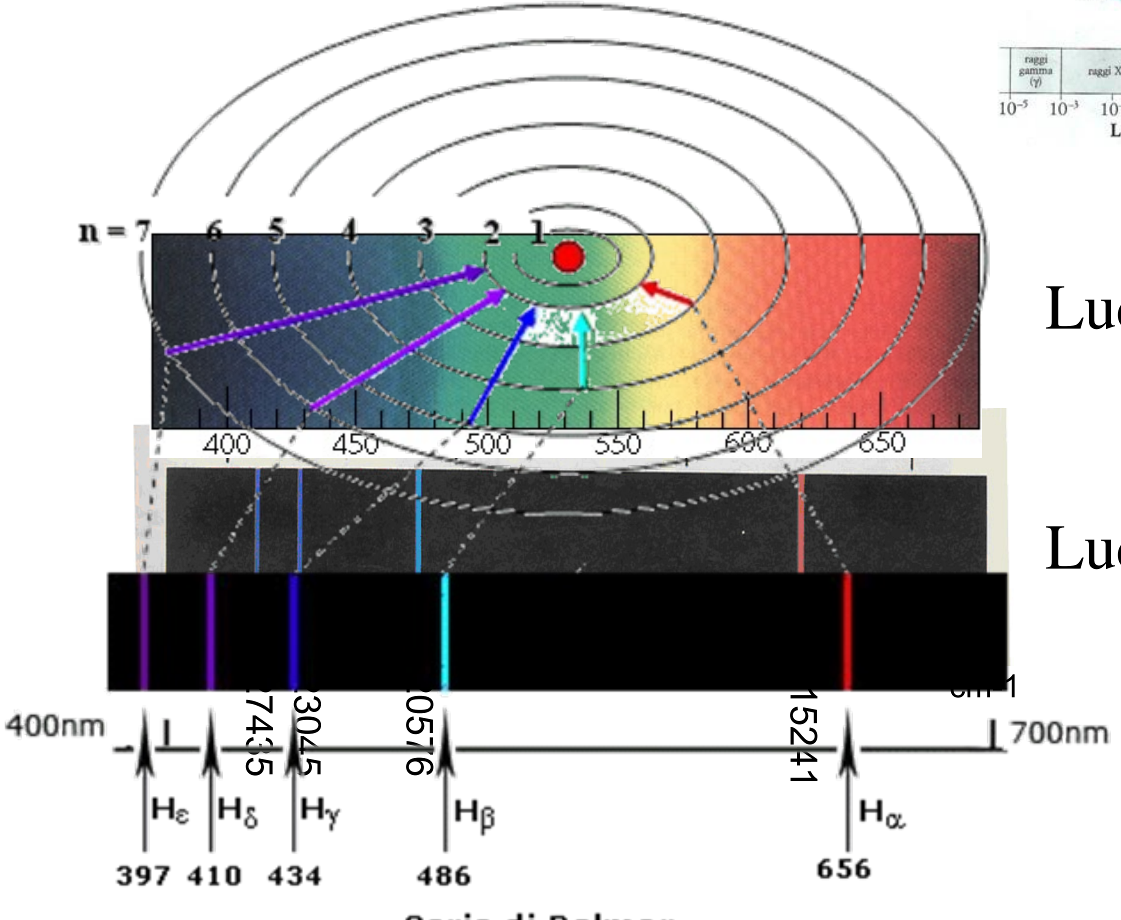
Spettroscopia di emissione atomica







9.2 La luce bianca si separa nelle sue componenti quando passa attraverso un prisma.



Luce bianca

Luce emessa dall' H

Problematiche dell'analisi elementare in ambienti ostili

1) Calibrazione strumentale

2) Matrix match standards

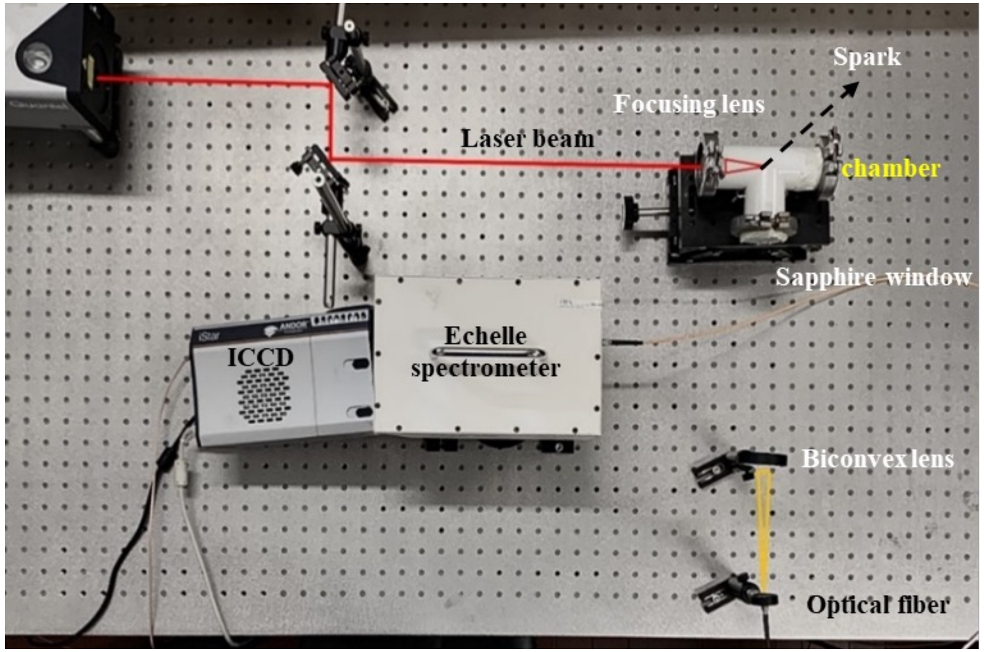
3) Curve di calibrazione

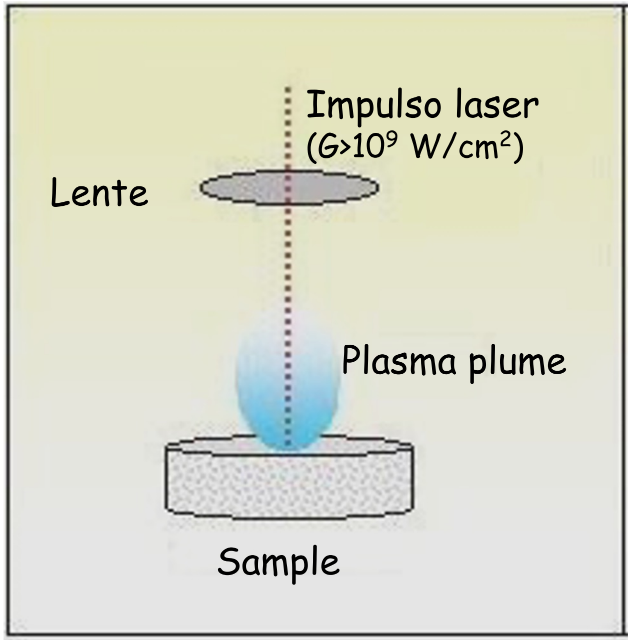
Stabilità e riproducibilità condizioni sperimentali e cammino ottico

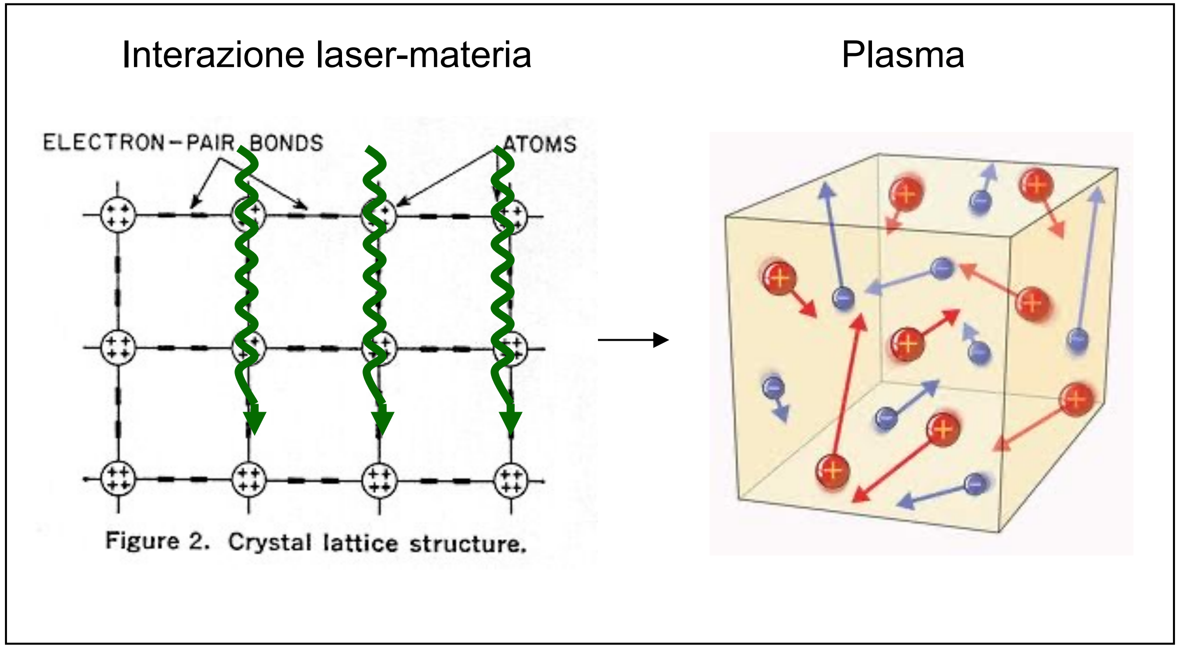
Standard con matrici simili al campione

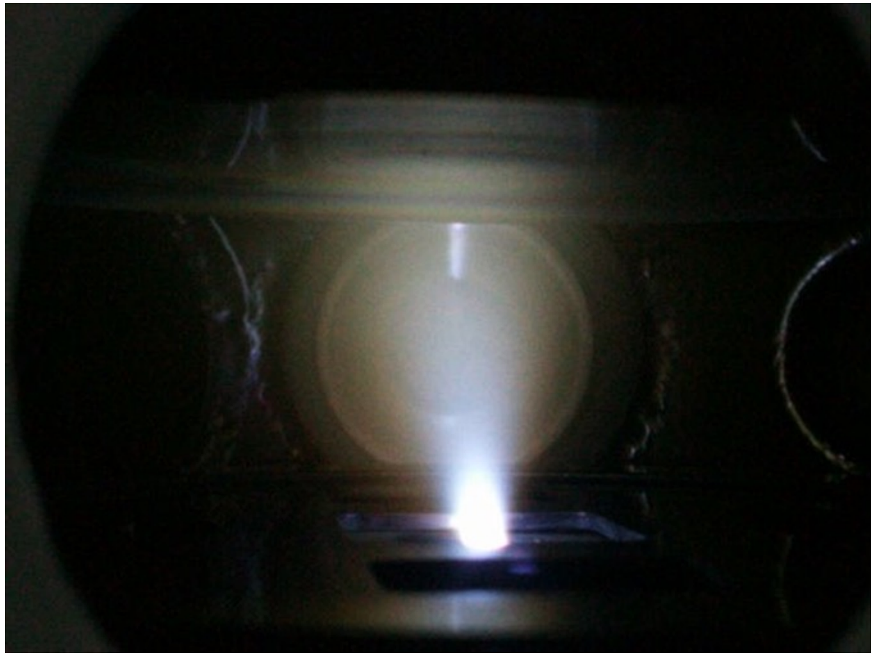
Quantità di campione nota e riproducibile

IMPOSSIBILE

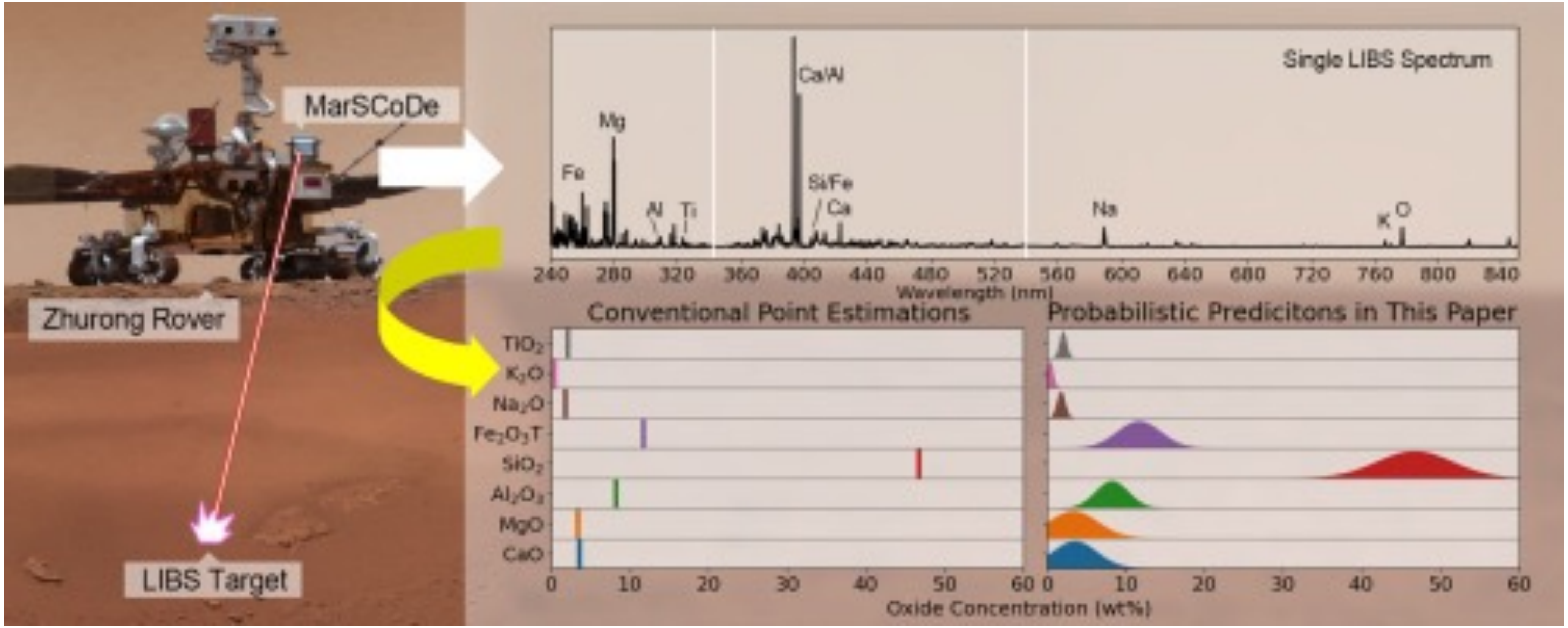

Spark
Focusing lens
Laser beam
chamber
Sapphire window
ICCD
Echelle spectrometer
Biconvex lens
Optical fiber

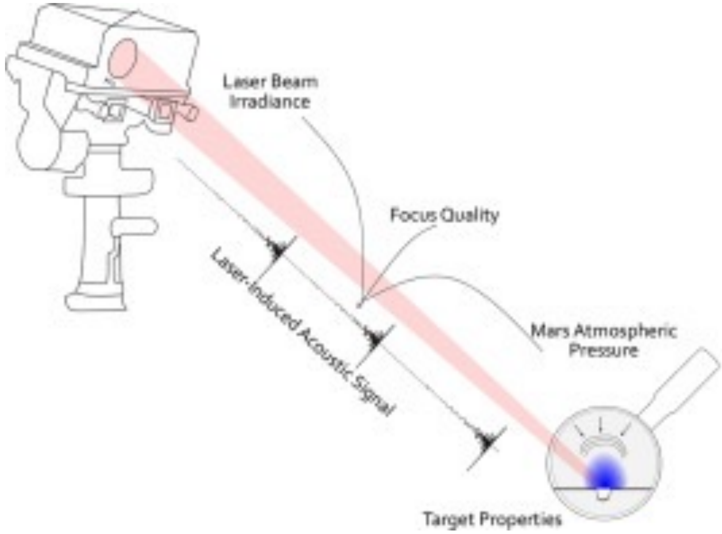

Impulso laser
(G>10^9 W/cm^2)
Lente
Plasma plume
Sample

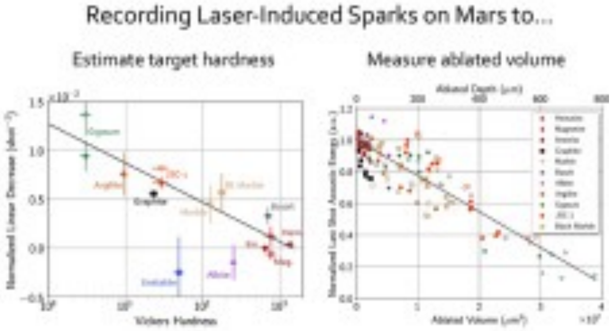

Interazione laser-materia
Plasma
ELECTRON-PAIR BONDS
ATOMS
Figure 2. Crystal lattice structure.

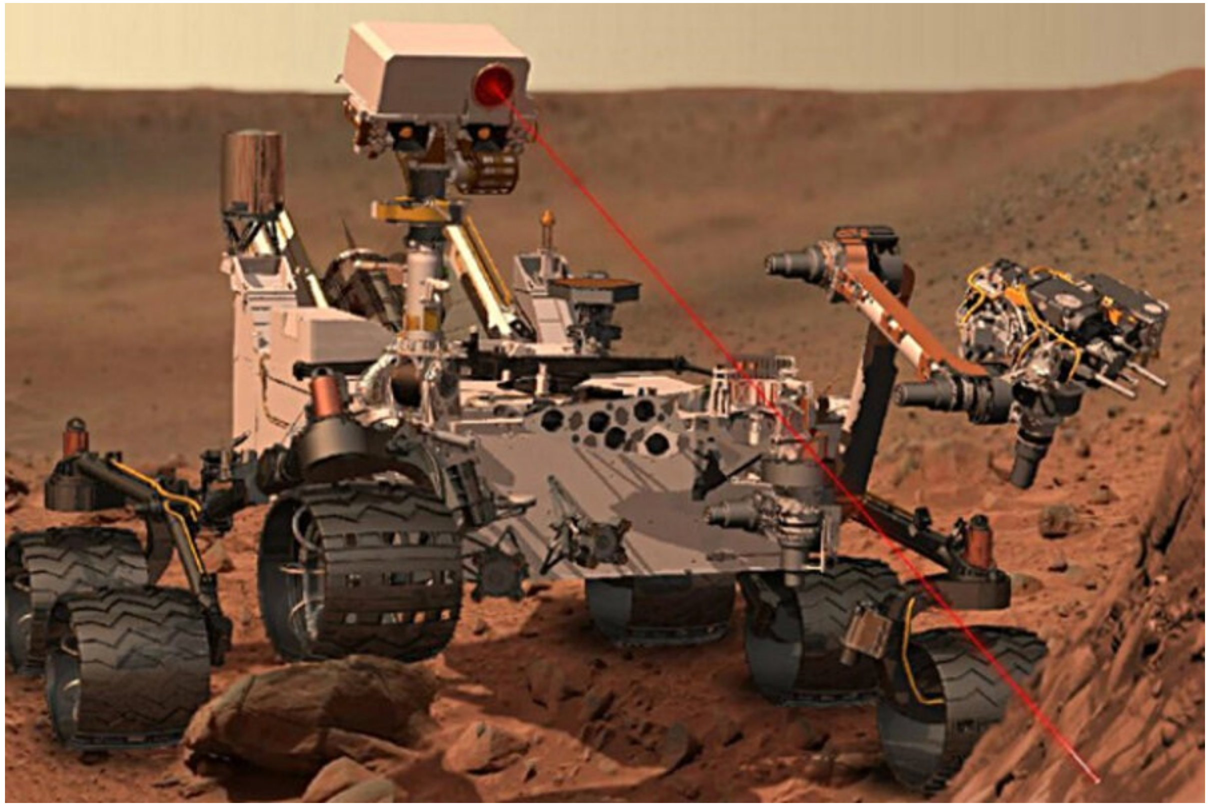


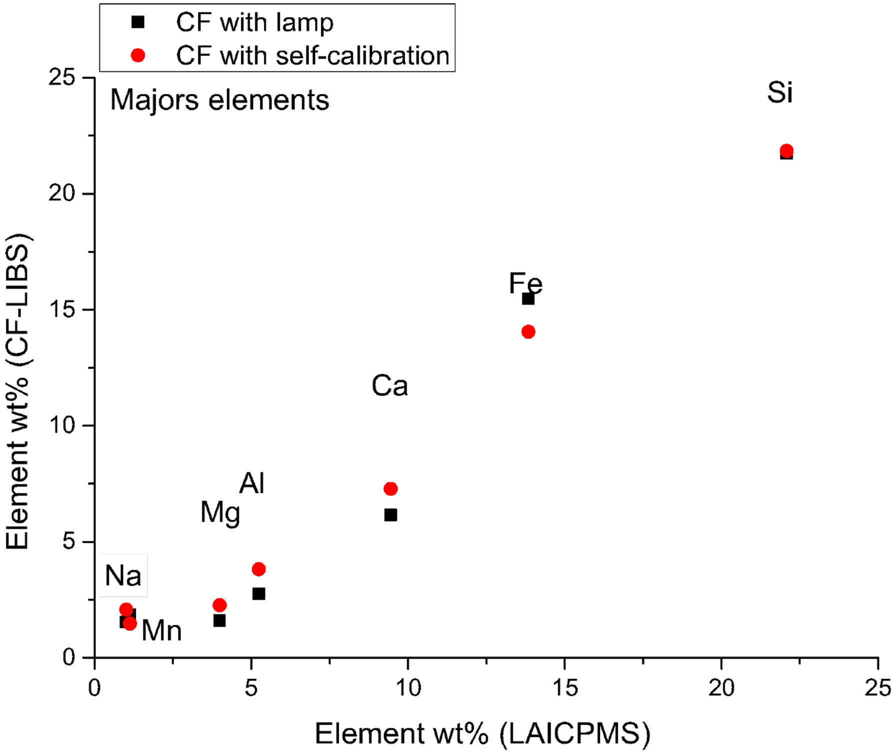
Esplorazione di Marte



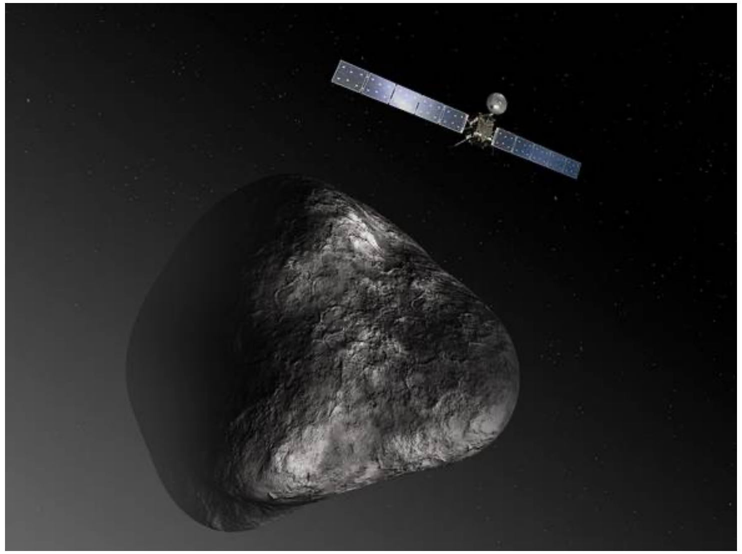

Laser Beam Irradiance
Focus Quality
Laser-Induced Acoustic Signal
Mars Atmospheric Pressure
Target Properties


Recording Laser-Induced Sparks on Mars to...
Estimate target hardness
Measure ablated volume




CF with lamp
CF with self-calibration
Majors elements
Si
Fe
Ca
Al
Mg
Na
Mn
Element wt% (CF-LIBS)
Element wt% (LAICPMS)
0
5
10
15
20
25

LIBS and Space Exploration

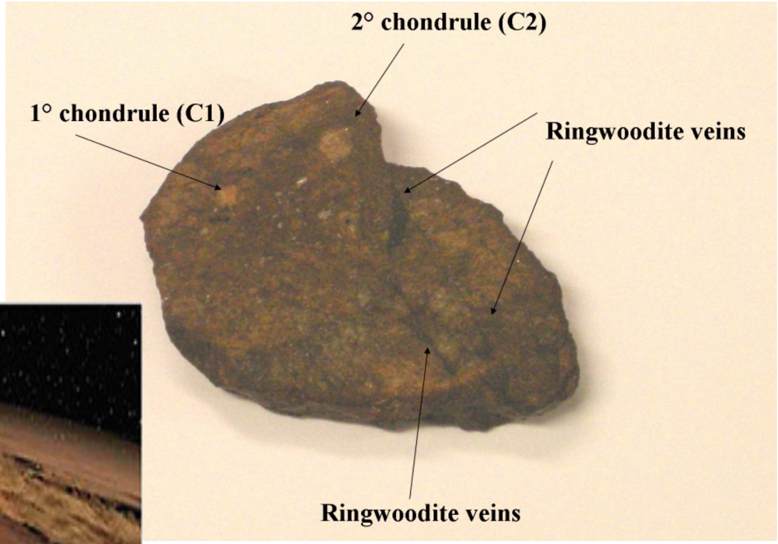


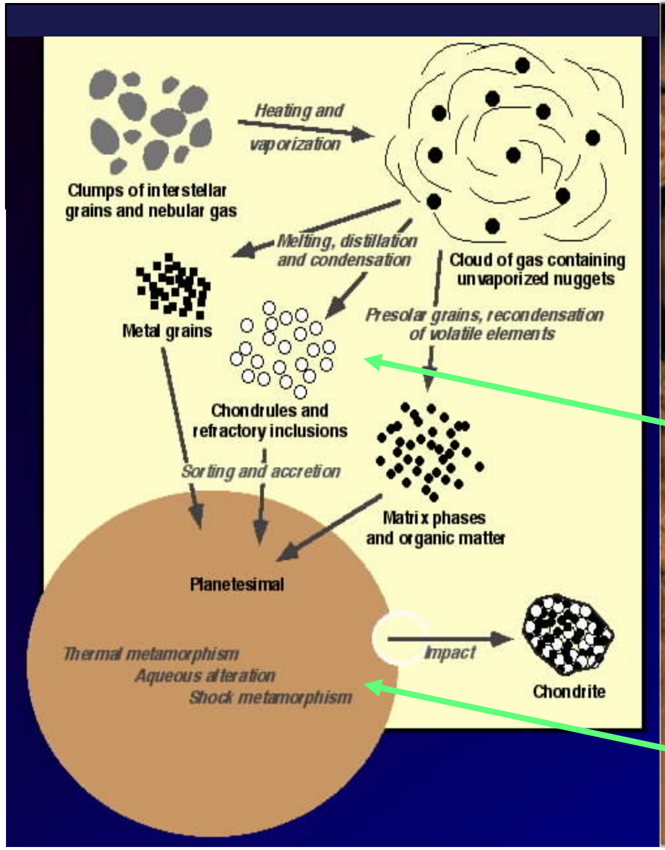
Asteroids, comets and meteorites

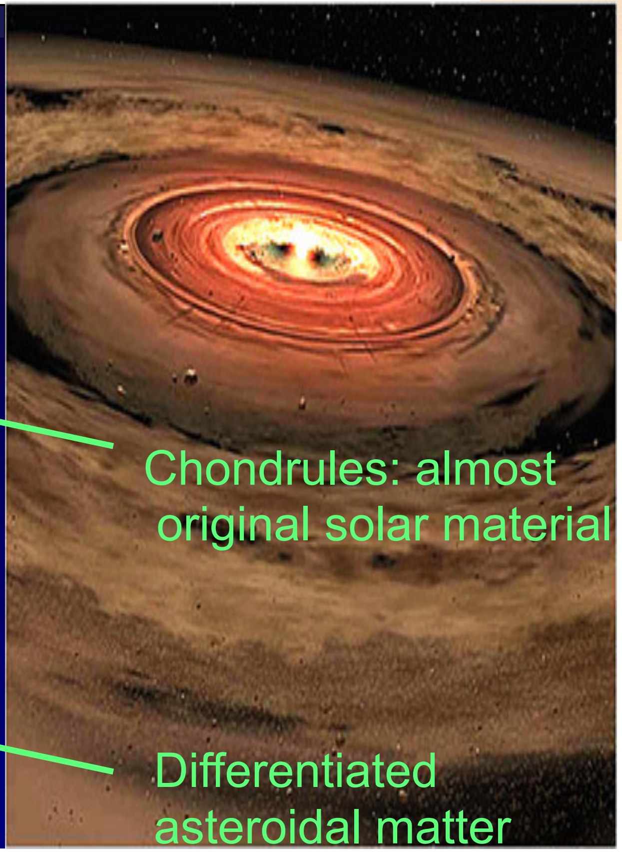
PON "Apulia Space" (PON03PE_00067_6)

LIBS on meteorites as a probe of the early solar system

First test case: chemical composition of chondrites and chondrules







2.6. Iron alloys analysis: iron meteorites

Sikhote Alin

Toluca

Campo del cielo

	CF (50 ns)			Literature			CF (5000 ns)		
	Fe	Ni	Co	Fe	Ni	Co	Fe	Ni	Co
Sikote Alin	93.0	6.3	0.8	93.5	6.0	0.48	94.0	5.7	0.6
Toluca	92.3	6.9	0.8	91.5	8.2	0.45	92.0	7.1	0.35
Campo del Cielo	93.1	6.2	0.5	92.6	6.9	0.50	91.0	8.0	0.7

Chemical elemental analysis

wt %	*Dhofar 019*		*Dhofar 461*		*Sahara 98222*	
	LIBS	**Literature[2]**	**LIBS**	**Literature[3]**	**LIBS**	**Literature[4]**
Al	1.4 ± 0.2	3.40	14 ± 1	15.50	0.88 ±0.09	1.22
Ti	0.45 ± 0.06	0.37	0.25 ± 0.04	0.13	0.060 ±0.009	0.063
Mg	9.5 ± 0.9	8.80	1.5 ± 0.2	2.40	13 ±1	14.9
Mn	0.35 ± 0.04	0.38	0.050 ± 0.005	0.05	0.26 ±0.03	0.257
Cr	0.6 ± 0.1	0.40	-	-	0.95 ±0.09	0.388
Ca	3.6 ± 0.6	5.20	12 ± 1	11.90	1.0 ±0.1	1.31
Fe	17 ± 2	14.70	4.9 ± 0.5	3.17	21 ±2	21.5
Si	24 ± 2	22.62	22 ± 2	21.00	20 ±2	18.5
Ni	-	-	-	-	0.22 ±0.02	1.2
Co	-	-	-	-	0.014 ±0.002	
O_{calc}	42 ± 6	44.20	44 ± 5	45.00	39 ±4	37.7

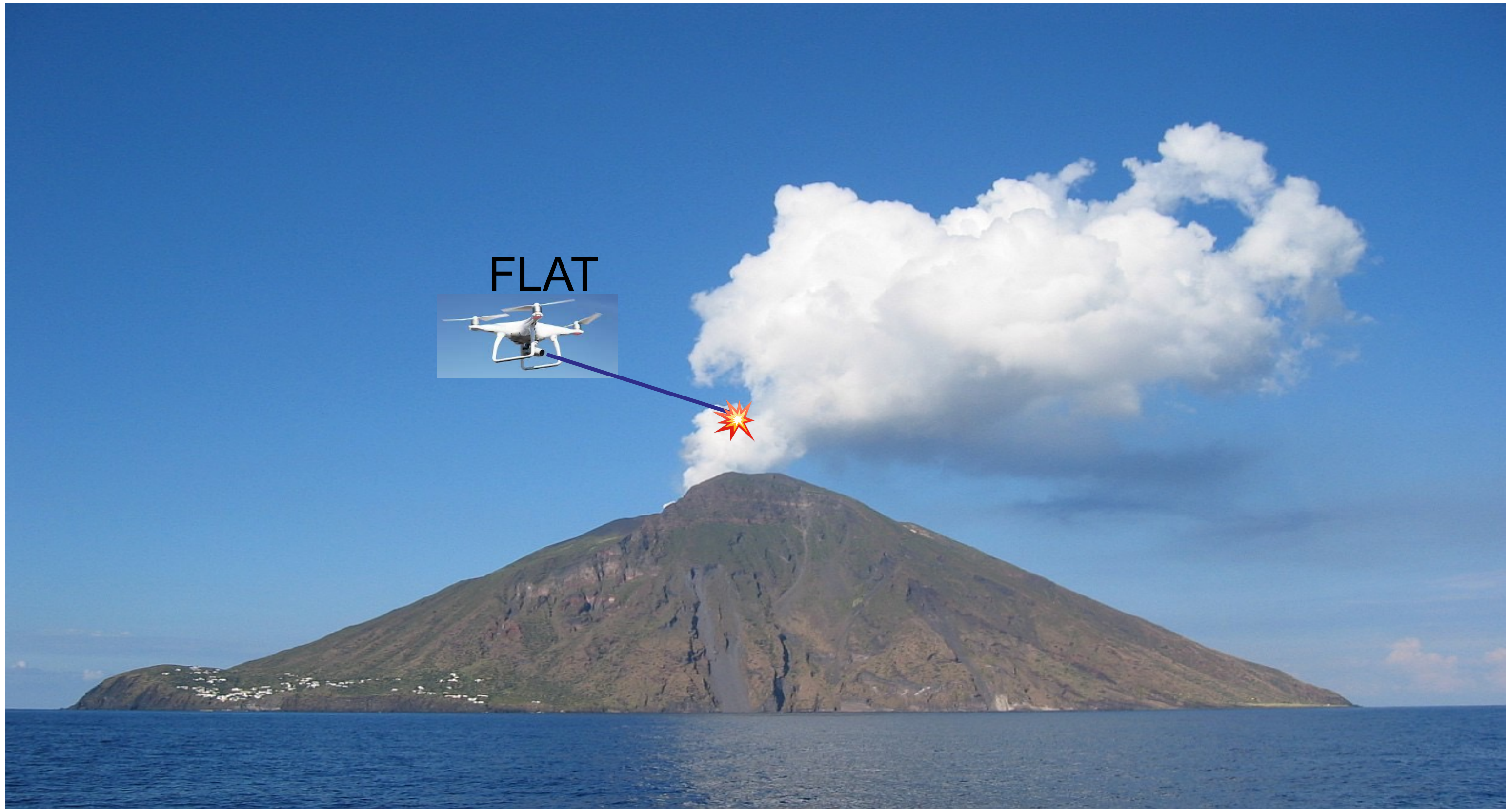
[2]Taylor et al., 2002
[3]Wasson et al., 1988

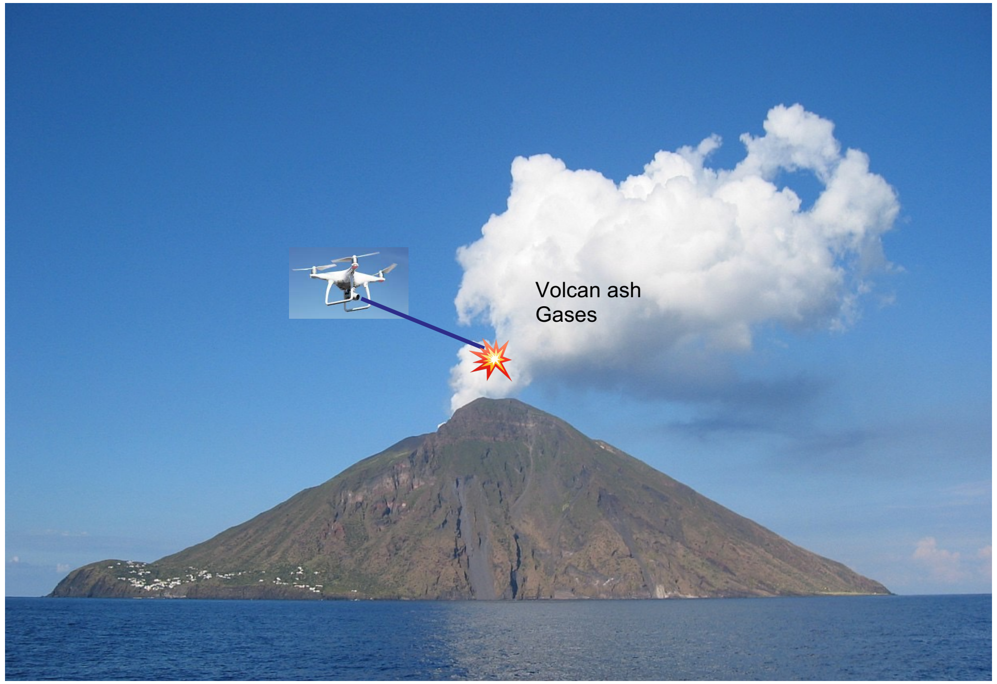
wt %	*Sikhote Alin*		*Campo del Cielo*		*Toluca*	
	LIBS	**Literature[2]**	**LIBS**	**Literature[3]**	**LIBS**	**Literature[3]**
Fe	94 ± 13	93.49	91 ± 14	92.61	92 ±13	91.49
Ni	5.7 ± 0.6	6.03	8 ± 1	6.94	7.1 ± 0.8	8.02
Co	0.6 ± 0.1	0.48	0,7 ± 0.1	0.45	0.34 ± 0.07	0.49

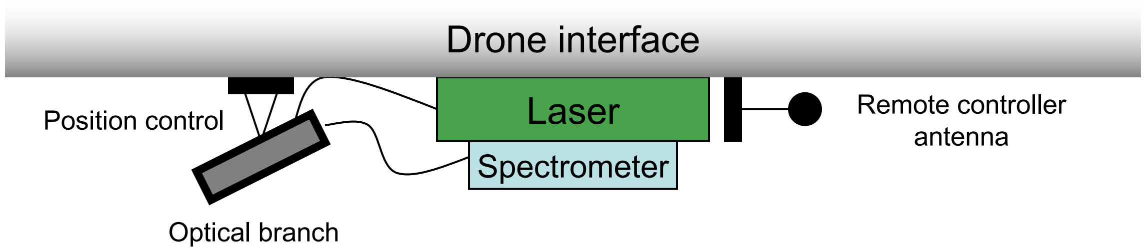
[2]Wasson et al., 2007
[3]Wasson et al., 2002

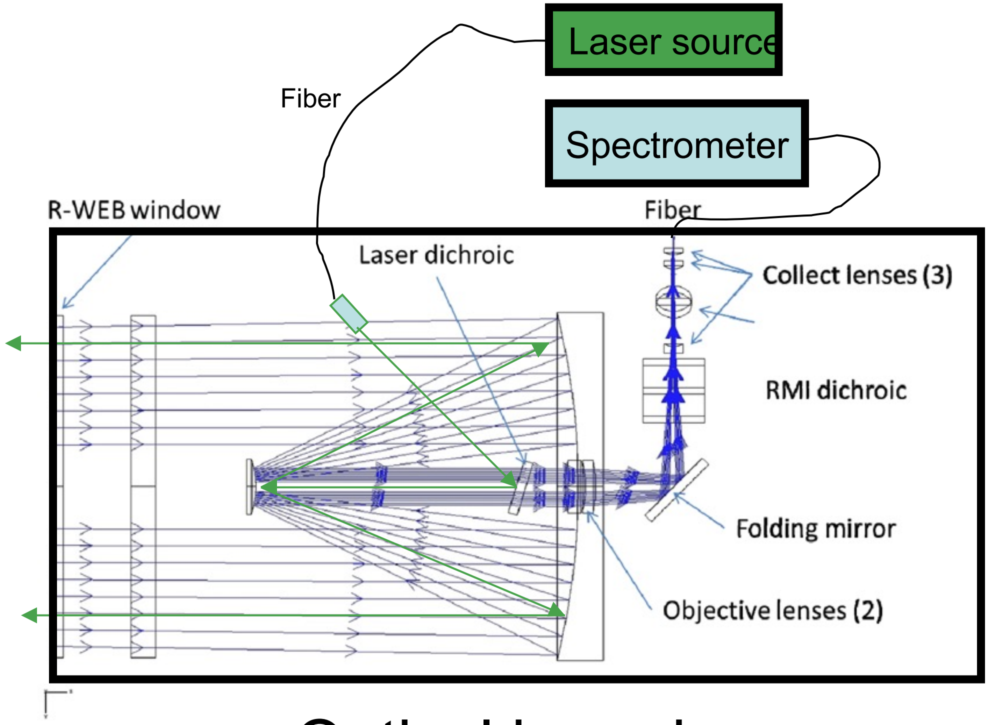
Spoke VS3	Earthquake and volcanoes
WP 2	Innovation in multiparametric monitoring on volcanoes

Monitoraggio Plume vulcanici

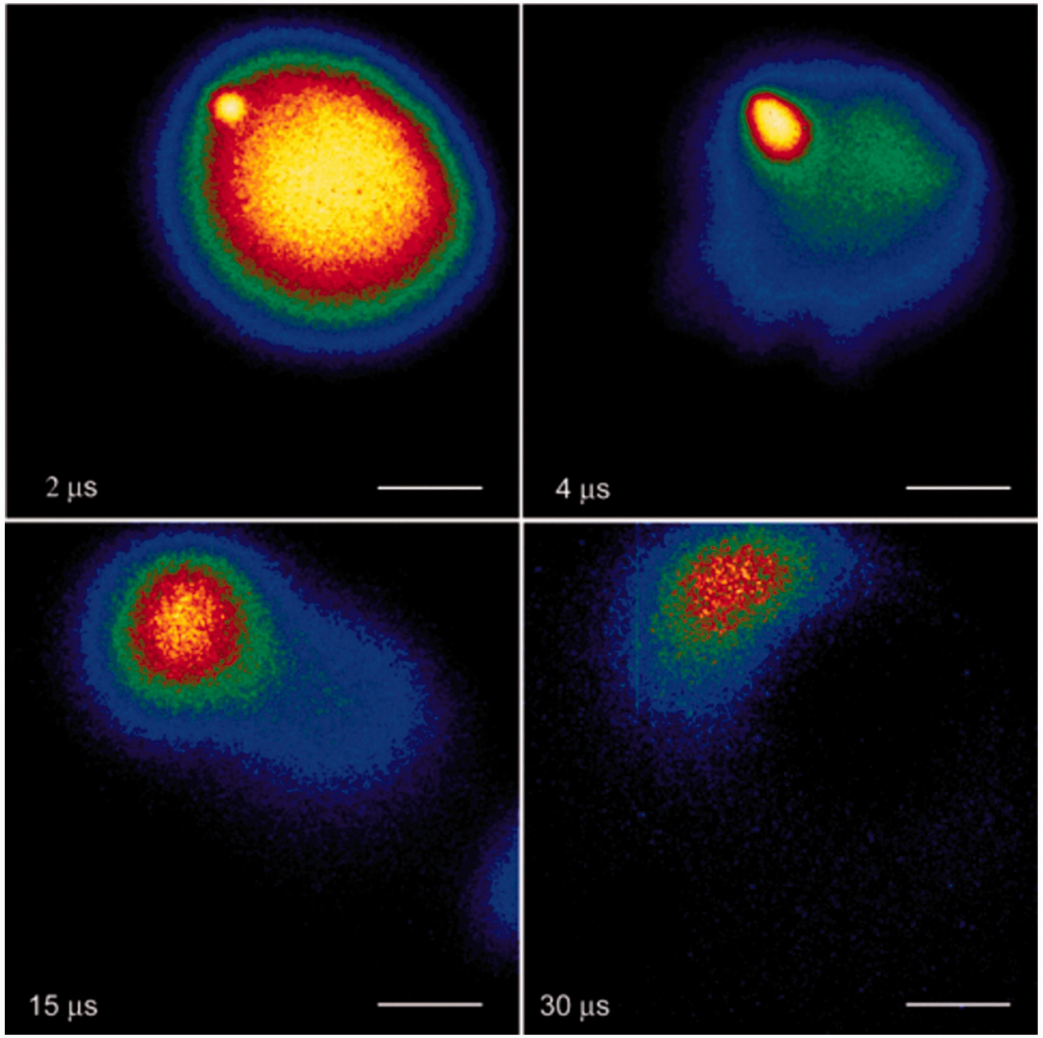


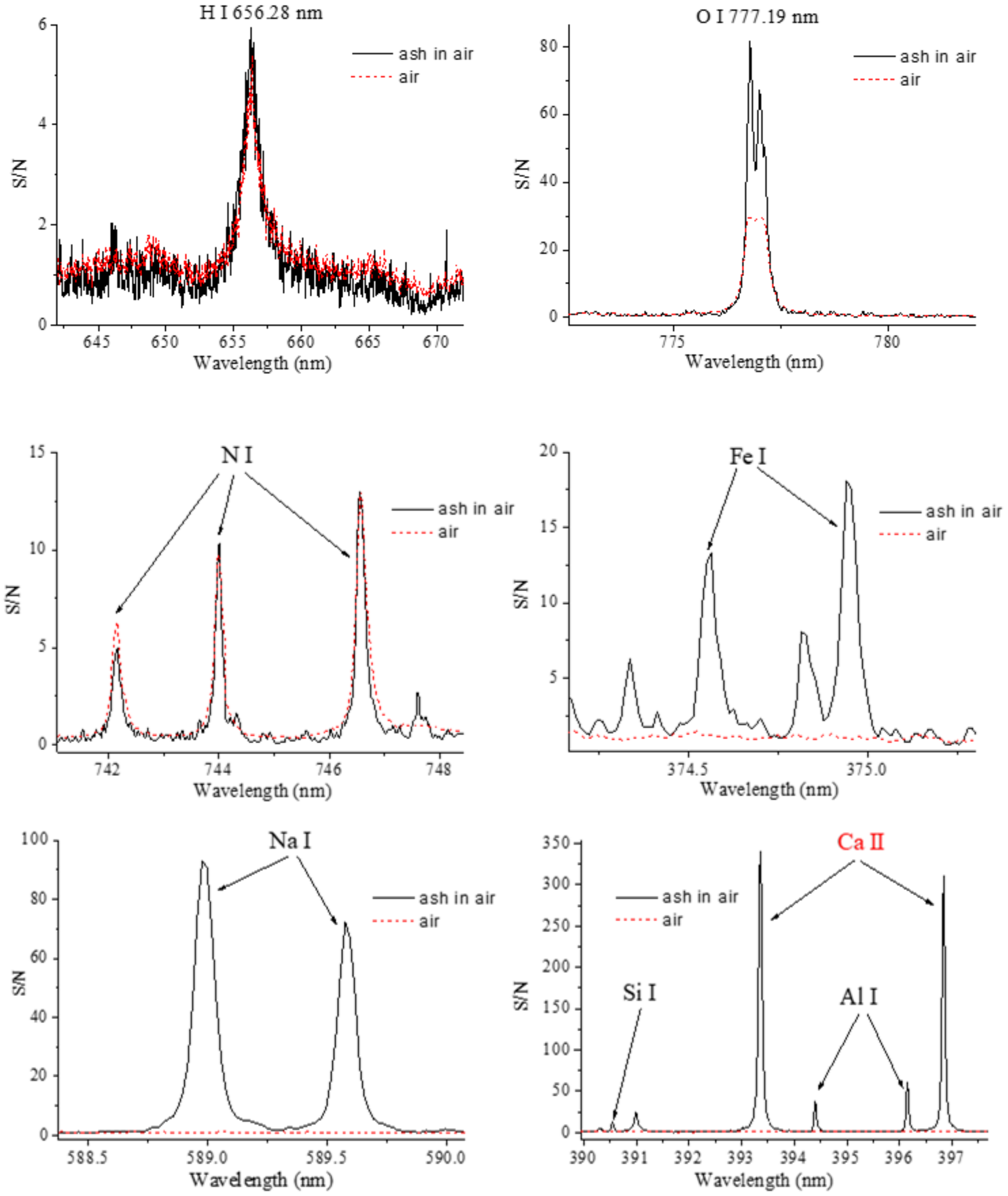






Optical branch



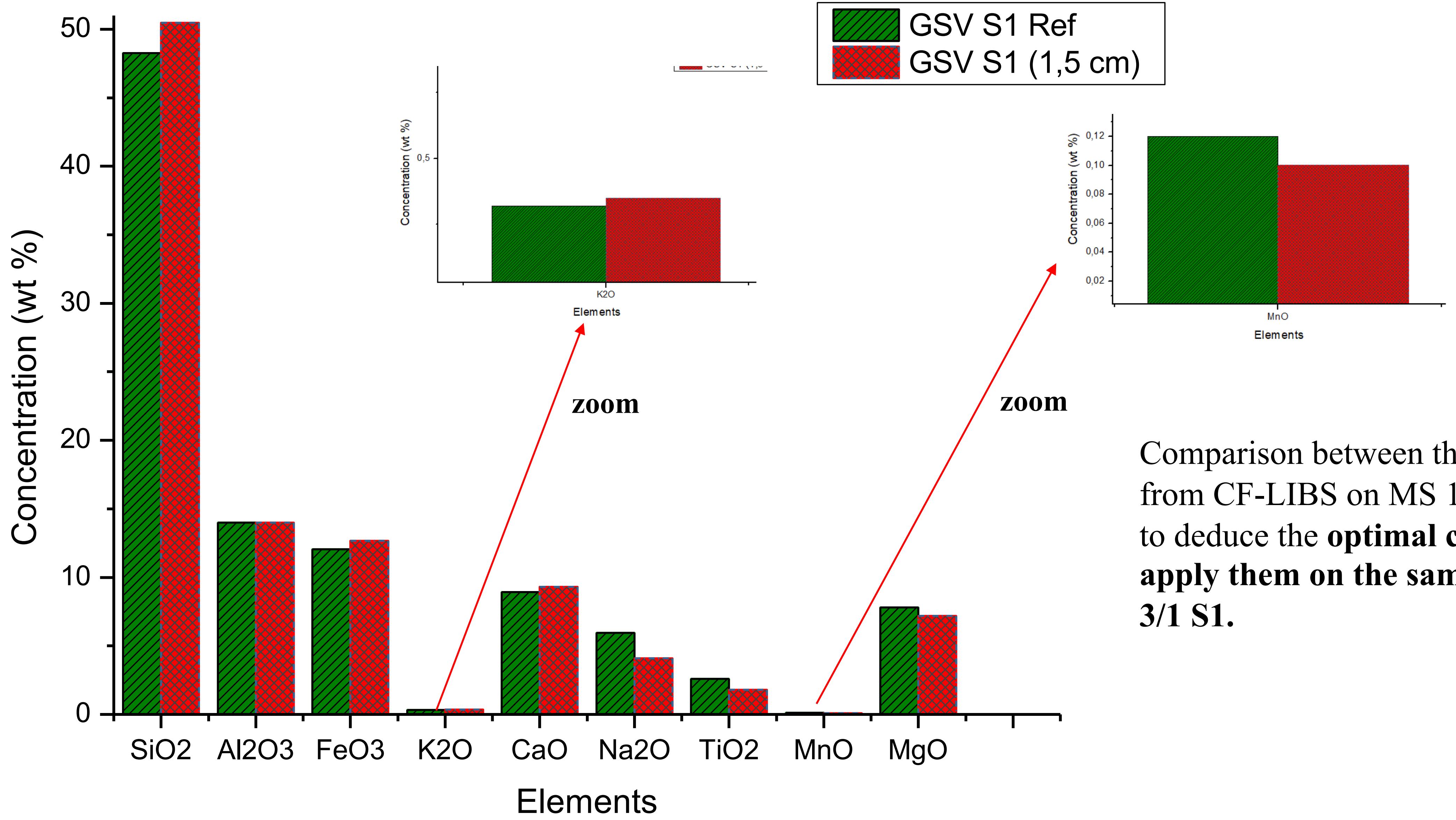


Hohreiter V., Hahn D.W. "Plasma-Particle Interactions in a Laser-Induced Plasma: Implications for Laser-Induced Breakdown Spectroscopy". Anal. Chem 2006; 78(5): 1509–1514

Volcanic ash analysis

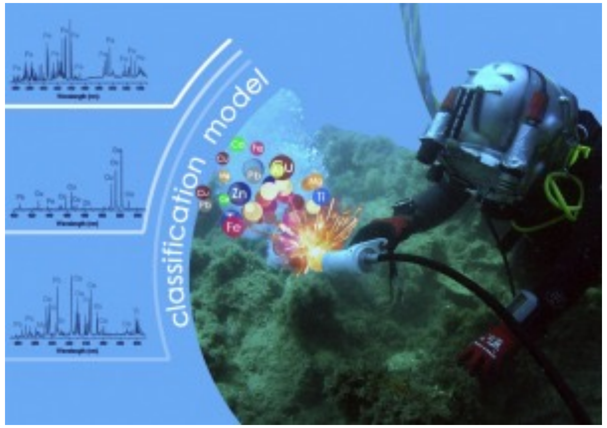
Calibration-Free Laser Induced Breakdown Spectroscopy : GSV 3/1 S1

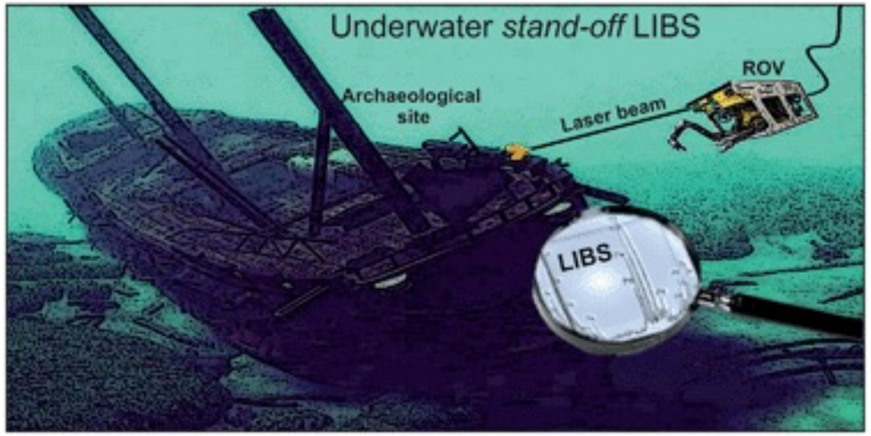
Distance between the laser pulse and the sample **1,5 cm** and laser energy **150 mJ**

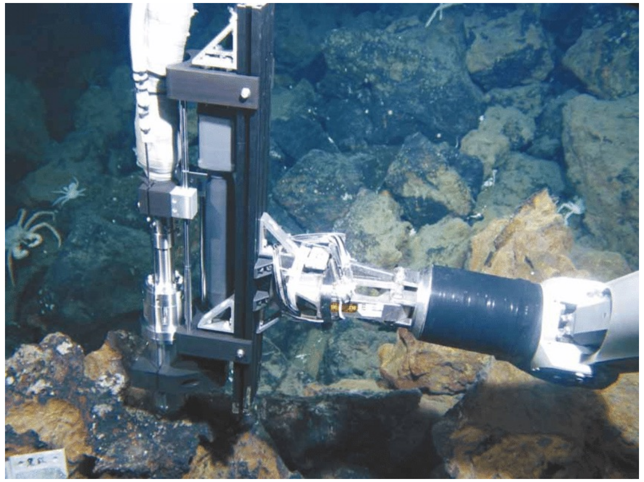


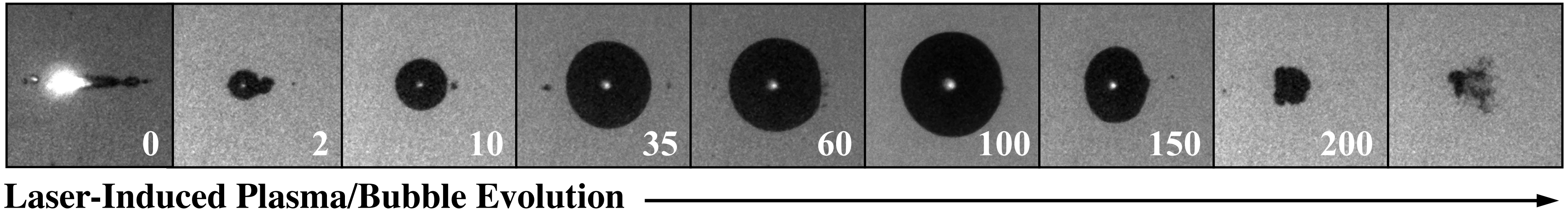
Comparison between the results obtained from CF-LIBS on MS 151/6 ash allowed to deduce the **optimal conditions and apply them on the same size ash GSV 3/1 S1.**

Esplorazione del mare

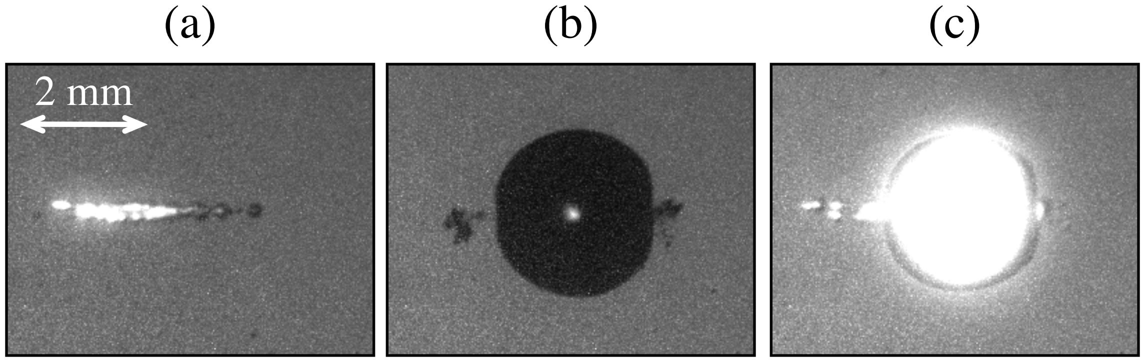








Evolution of the laser-induced bubble formed in bulk aqueous solution (P = 1 bar) using a single laser pulse (E1 = 7 mJ/pulse) incident from the left of the images. For all images, td = 800 ns, tb = 1 μs, and P = 1 bar. The delay following the laser-pulse, Δt, was varied and is indicated in the bottom right-hand corner of each image. The bubble had a maximum radius of approximately 2.5 mm (Δt = 100 μs). Each shadowgram corresponds to 4 x 4 mm region around the focal volume. The bright spot in the middle of the bubble (2 ≤ Δt ≤ 150 μs) is transmitted light from the background illumination source (not plasma emission).



Shadowgraph images of (a) SP-LIBS plasma, using E2 only; (b) laser-induced bubble, using E1 only, Δt = 60 μs; and (c) DP-LIBS plasma, using E1 and E2, Δt = 60 μs. E1 = 7 mJ/pulse and E2 = 30 mJ/pulse. For all images, td = 800 ns, tb = 1 μs, and P = 1 bar. The laser pulse was incident from the left of the images. Each shadowgram corresponds to 4 x 5 mm region around the focal volume. The bright spot in the middle of the bubble in (b) is transmitted light from the background illumination source (not plasma emission).

Images by S.M. Angel, University of South Carolina https://youtu.be/fEZ5dEi4oPo